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Attorney Docket No. 25539

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Group Art Unit: 2877

COHEN et al.

Serial No.: 10/606,199

Filed: June 26, 2003

Title: **THIN FILMS MEASUREMENT METHOD AND SYSTEM**

TRANSMITTAL LETTER

Commissioner of Patents
P.O. Box 1450
Alexandria, Va 22313-1450

Sir:

Submitted herewith for filing in the U.S. Patent and Trademark Office is the following:

(1) Transmittal Letter;
(2) Request for Priority;
(3) Priority Document No. 150438

The Commissioner is hereby authorized to charge any deficiency or credit any excess to Deposit Account No. 14-0112.

Respectfully submitted,

NATH & ASSOCIATES PLLC

By: [signature]
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REQUEST FOR PRIORITY UNDER 35 U.S.C. §119

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In the matter of the above-captioned application, notice is hereby given that the Applicant claims as priority date June 26, 2002, the filing date of the corresponding application filed in ISRAEL, bearing Application Number 150438.

A Certified Copy of the corresponding application is submitted herewith.

Respectfully submitted,
NATH & ASSOCIATES PLLC

Date: June 17, 2004

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משרד המשפטים
לשכת הפטנטים

This is to certify that annexed hereto is a true copy of the documents as originally deposited with the patent application of which particulars are specified on the first page of the annex.

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חוק הפטנטים, תשכ"ז - 11967

PATENT LAW, 5727 - 1967

בקשה לפטנט

Application for Patent

לשימוש הלשכה
For Office use

מספר: Number	150438
תאריך: Date הוקדם/נדחה Ante/Post-dated	26-06-2002

אני, (שם המבקש, מענו ולגבי גוף מאוגד - מקום התאגדותו)

I (name and address of applicant, and in case of body corporate, place of incorporation)

נובה מכשירי מדידה בע"מ
חברה ישראלית, מוייצמן פארק למדע, ת"ד 266, רחובות 76100

Nova Measuring Instruments Ltd., Weitzmann Scientific Park, P.O.B. 266, Rehovot 76100

בעל אמצאה מכח ______ הדין ______ ששמו הוא

of a invention the title of which is — Right of Law — Owner by virtue of

בעברית (Hebrew)

שיטה למדידת שכבות דקות

באנגלית (English)

Method of Thin Films Measurement

מבקש בזאת ינתן לי עליה פטנט

Hereby apply for a patent to be granted in respect thereof

* בקשת חלוקה Appl. Of Div.	*בקשת פטנט מוסף Appl. for Patent Add.	* דרישת דין קדימה Priority Claim		
מבקשת פטנט to Patent/Appl No. .... 'מס dated .... מיום	* לבקשה/לפטנט to Patent/Appl. No. .... 'מס dated. .... מיום	מספר/סימן Number/Mark	תאריך Date	מדינת האגוד Convention Country
*יפוי כח: כללי/מיוחד רצ"ב/עוד יוגש P.O.A.: general/indiv/-attached/to be filed later Filed in case הוגש בענין				
המען למסירת מסמכים לישראל Address for services in Israel: נובה מכשירי מדידה בע"מ חברה ישראלית, מוייצמן פארק למדע, ת"ד 266, רחובות 76100				
חתימת המבקש Signature of Applicant Moshe FINAROV, Director of Technology		היום 26 This לחודש 06 Month שנת 2002 Year		
		לשימוש הלשכה For Office Use		

טופס זה, כשהוא מוטבע בחותם לשכת הפטנטים ומושלם במספר ובתאריך ההגשה, הינו אישור להגשת הבקשה שפרטיה רשומים לעיל.

This form, impressed with the Seal of the Patent Office and indicating the number and date of filing, certifies the filing of the application the particulars of which are set out above.

Delete whatever is unapplicable מחק את מיותר

Method of Thin Films Measurement

שיטה למדידת שכבות דקות

FIELD OF THE INVENTION

This invention is generally in the field of optical measurement techniques, and relates to a method and system for thin films (layers) measurement. The present invention is particularly useful for process control in the manufacture of semiconductor devices such as wafers comprising multi-layer structures (film stack).

BACKGROUND OF THE INVENTION

Integrated circuits are multi-layer structures produced by applying a sequence of different layers deposition and at least partial removal steps to a semiconductor wafer. Various manufacturing steps in the manufacture of semiconductor devices require measurements of thickness or other characteristics of each layer of a semiconductor wafer.

Optical methods for on-line or integrated measurement of the parameters of dielectric films (e.g., film thickness) are known in the art. Most of these techniques are based on reflectometry in broaden spectral range, e.g. from DUV to NIR spectral range.

It is especially important to determine optical properties of each layer (film) of the actual stack after performing all the processing steps and before performing further measurements such as uppermost layer thickness, etc. Unfortunately, in cases when measurements are performed on entire stack comprising different layers that affect similarly on spectral response, accurate determining properties of each separate layer are almost impossible.

There is accordingly a need in the art to facilitate measurements on entire stack providing a novel method of optical measurements.

DETAILED DESCRIPTION OF THE INVENTION

There are many situations that doing the measurements prior to such processing step will give advantage and actually will enable the option for the measurement at all. In these cases the ability to use measurements before process step and use the data will determine the ability to have accurate enough measurement at the post measurement and hence influence the decision to use the metrology tool for process control. There are two basic types for using the Pre processing measurement: "Discrimination" and "Complementary" data. In both cases the

pre-processing measurement on the same sites with the post measurement plus injection of the information are key issue to enable certain type of measurement at all or with the required accuracy. The main principles of the construction and operation of a measurement system including the zero-order detection spectrophotometer comprising imaging channel for pattern recognition is disclosed in U.S. Patent No. 6,045,433, assigned to the assignee of the present application. This document is therefore incorporated herein by reference with respect to this specific example.

A. <u>Discrimination improvement by reducing number of free parameters for interpretation.</u>

In certain cases the measurement prior to processing can give the ability to have better discrimination between parameters that have a non-orthogonal contribution to the measurement. One example for such approach is the measurement of thin layers of Silicone Oxide (SiO_2) residues above other transparent layers, e.g. Silicon Nitride (Si_3N_4) in case of monitoring STI (shallow trench isolation) – residues. The spectrophotometer measurement in a pre- polish state yields a spectrum that is related to the Silicon Nitride thickness or Oxide thickness together. The analysis of the spectrum to understand the two thickness values d_1 and d is done using regression fit. The limitation in this case comes from the fact that the basic discrimination of each transparent layers is proportional to n*d, wherein n is refraction index. So, measurement of $n_1*d_1+n_2*d_2$ for $d_2<<d_1$ should be problematic as long as the ratio of n_2*d_2 is << $n_1*d_1+ n_2*d_2$. However for a pre polish state this last condition is not valid and the measurement can be accurately done using the interpretation of both parameters simultaneously since each (d) thickness have significant effect on the spectrum. So measurement of d_1 in a pre- polish state can be done and then inject the value to the post polish measurement. As was found, the layer of Silicone Oxide of less than 100Åcould not be distinguished from the beneath Silicon Nitride layer by spectrophotometric measurements. Typical example presenting the situation is stack comprising 0 Å Silicon Oxide layer, 970 Å Silicon Nitride layer and 80 Å STI. The standard approach so far was to perform post-polishing measurements and simultaneous interpretation for both Silicon Nitride and Silicon Oxide Residues above it via Merit Function (MF) calculation for regression fit. The rate of MF change vs. thickness change of each material presents the

sensitivity of the regression fit to this parameter. It was found by that there is no sensitivity to Silicon Oxide thickness, while for the Silicon Nitride thickness the rate of change is much sharper. Since the ability to converge to right Silicon Nitride thickness is limited because of natural errors of the experimental spectrum measurement. The situation of such case will cause during fit small error in the nitride while much higher (order of magnitude) error in the Silicon Oxide thickness.

In accordance with one aspect of the present invention, the in order to avoid uncertainty in measurements of above described structures, pre-polishing measurements is applied. For typical situation of the stack comprises 4840Å Silicon Oxide layer, 960Å Silicon Nitride layer and 80Å STI. Pad Oxide/Si) the MF slopes for the 2 thickness Oxide and Nitride are significantly high thus ensure good convergence sensitivity for both parameters. The mutual effect of one thickness on the other thickness is minor and good accuracy can be achieved even for simultaneous interpretations. In Fig. 1 there is a presentation of 1Dimensional MF plot, MF vs. Silicon Oxide thickness. The minimum at zero thickness is well defined. The Nitride thickness, which could be easily and accurately interpreted using pre-polished state of the wafer. In this way ambiguity regarding small errors in the Silicon Nitride thickness is avoided and large errors in the oxide thickness can be avoided.

Fig. 2 illustrates a flow chart of a method in accordance with one aspect of the present invention. As shown in Fig. 2, the method comprising pre-polishing and post-polishing thickness measurements in the same measurement site. Further interpretation is done by assuming that no top Silicon Oxide layer is presented in the stack. In case when the Silicon Nitride thickness is smaller than those found from pre-polishing measurements (actually it may be measured thickness minus very small typical measurement error), the measurement is finished by presenting Silicon Nitride actual thickness result and zero Silicon Oxide thickness (i.e. no residuals). Contrary, when Silicon Nitride thickness is equal or higher those found from pre-polishing measurements, the interpretation step is implemented for Silicon Oxide layer with known (pre-polishing) Silicon Nitride thickness.

It should be noted that all pre-polishing (CMP) measurement could be carried out as post CVD measurements, i.e. after performing the deposition step. Such measurements

could be performed by integrated with CVD processing tool measurement station, both in vacuum or air environment.

Another typical example is thickness measurements for Physical Vapor Deposition process (PVD) of thin metal films.

In this case the measurement of the pre process step could provide data that otherwise due to measurement limitations cannot be measured by standard techniques. Such measurement could provide a set of starting condition for the next measurement e.g. underlying layers to improve the next measurement interpretations. A typical example for such state is the measurements of multi stacks of thin metals layers using optical methods. By additions of metal deposition steps the metal stack layers can become practically opaque. Therefore measurement of thin metal layers prior to additional step is enabler for achieving better accuracy measurement and actually may determine the need for such type of measurement. The simultaneous measurement of Tungsten (W) and Nitride Tungsten (WN) film sum is a very accurate measurement however it may have some mutual contribution from W film to WN film on the level of few angstroms. The simultaneous measurement of two thin metal layers, which may be suspected by error contribution from one metal to other metal, cannot be neglected. To eliminate any additional contribution and to have better repeatability for each of the layers in the W/WN stack there is an advantage to measure the metal layers after each deposition step and to transfer the previous measurement to the next measurement. For example taking such approach the calculation shows improvement in the repeatability from 2.5 Å to 1.1Å for the upper layer.

<u>B. Complementary data injected from pre processing measurement</u>

In accordance with another example of the present invention data injected from pre-processing measurement could be used for measurement layer thickness within such structures as trenches, holes, etc. based on scatterometry. In that case, the basic sensitive capability is the measurement of shape of features that were covered by Metal deposition (e.g. Sputtering or CVD etc.). The scatterometry technique could not resolve with required accuracy parameters of metal thickness (for layers thicker than few hundreds angstroms), and especially thickness of the metal layer that cover the sidewalls. However, its sensitivity to shape parameters such as trench slopes, trench depth, trench opening (CD top), is

extremely higher. In this case these shape parameters could be measured with very good repeatability and accuracy.

More specific is case of the barrier and seed layers deposition step that are a preliminary step for Electroplating step in Damascene process. Each deposition of metal is a stage for shape measurement based on the very sensitive parameters. Accurate and repeatable measurement on the same site prior and after each deposition step can yield different shapes that their subtraction presents an actual thickness of layer that was deposited in this process step.

The present invention may be used for measuring layers parameters (e.g. thickness) for controlling of various deposition steps. For example, measurement of barrier layer thickness values (in all direction sidewalls, bottom of trench) may be performed in accordance with the present invention in the following manner. First pre-processing measurement of the structure profile (shape) is performed prior to barrier layer deposition. Additional measurement of the structure profile in the same measurement site is performed after completing the barrier layer deposition. Actual thickness of deposited layer then is calculated as a difference between second and first profiles. It should be noted, that actually first measurement could be performed after completing the step of trench etching, e.g. using integrated with etcher measurement tools. The second measurement could be performed as pre- processing measurement for seed layer deposition step. Similar technique could be applied for control of seed layer deposition process. In that case, first measurement is performed prior to seed deposition step (or after barrier layer deposition) and second step is performed after completing the seed layer deposition (or prior to step of electroplating). Process control for electroplating providing information on metal layer thickness in all direction sidewalls, bottom of trench also could be provided in accordance with the present invention. In that case, first measurement is performed prior to electroplating step (or after seed layer deposition) and second step is performed after completing the step of electroplating (or prior to step of polishing or photolithography). Such process control for electroplating enables to eliminate or sufficiently to reduce void or non-sufficient coverage problems.

Table below illustrates analysis of such capability for pre- and post- seed layer deposition measurement. Presented is a calculation that was done using repeatability data

retrieved from optical scatterometry tool that give data for CD top and sidewall slopes of trench that was covered with metal. In this calculation the maximal error that can be caused by subtraction of two shapes (pre seed and post seed deposition) measured by sctterometry is analyzed.

	Measurement POST for known PRE profile	Measurement of PRE-error	Measurement PRE+ Measurement POST error
	SEED for known barrier profile	Barrier error	Seed with measured barrier problems
Contribution of reference point error "CD top" - STDEV[nm]	0.144	0.144	0.288
Error due to slope contribution – STDEV[nm]	0.951	0.951	1.903
Worse error for any point across profile – STDEV[nm]	1.095	1.095	2.191
Worse error for any point across profile - STDEV [% of seed thickness]	4.08%	4.08%	8.15%

Those skilled in the art will readily appreciate that many modifications and changes may be applied to the invention as hereinbefore exemplified without departing from its scope, as defined in and by the appended claims.

CLAIMS:

1. A method of thin films measurement as hereinbefore described and exemplified with reference to the accompanying drawings.

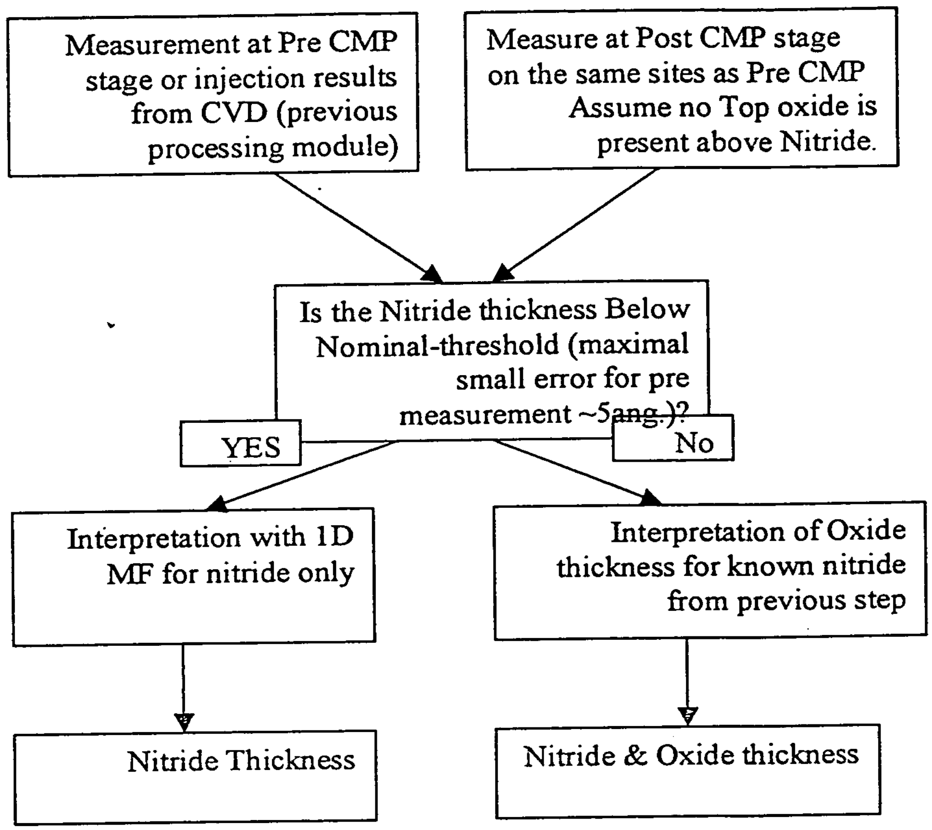
2. A method of semiconductor manufacturing process control as hereinbefore described and exemplified with reference to the accompanying drawings.

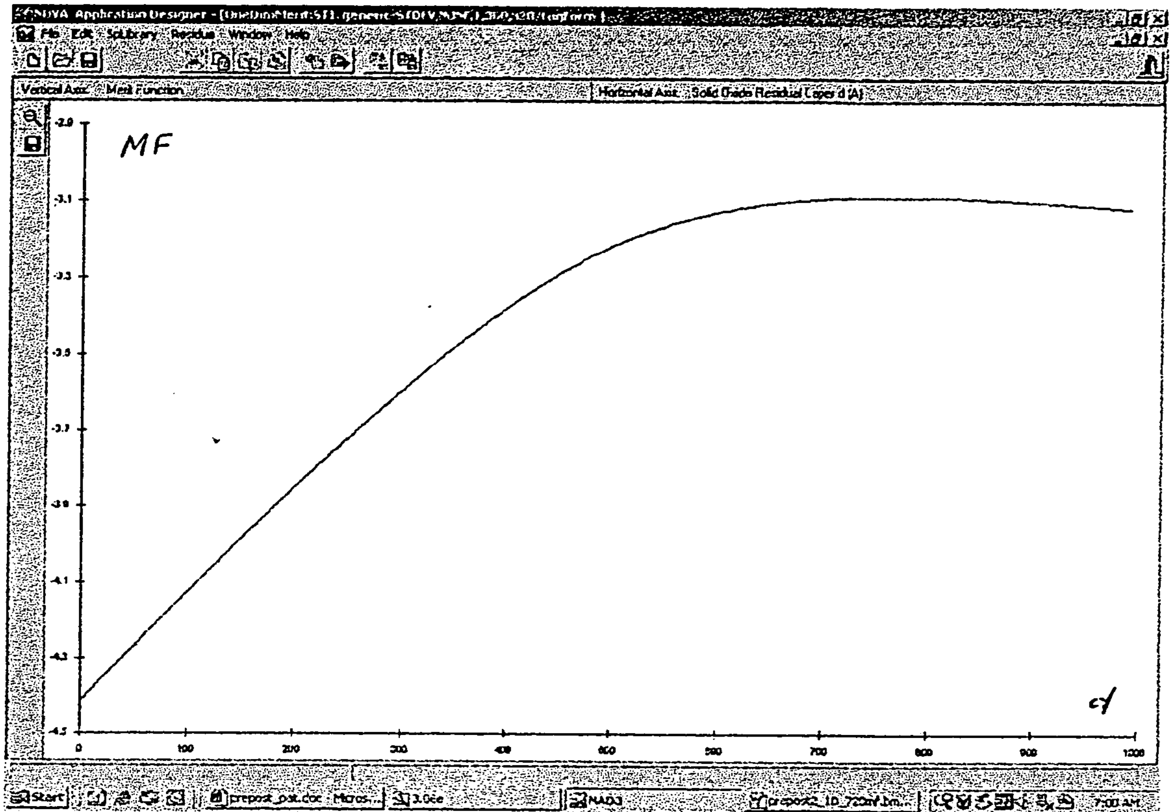
3. A method of metal layer parameters measurement as hereinbefore described and exemplified with reference to the accompanying drawings.

Applicant

Moshe Finarov,
Director of Technology

Fig. 2


Measurement at Pre CMP stage or injection results from CVD (previous processing module)
Measure at Post CMP stage on the same sites as Pre CMP Assume no Top oxide is present above Nitride.
Is the Nitride thickness Below Nominal-threshold (maximal small error for pre measurement ~5ang.)?
YES
No
Interpretation with 1D MF for nitride only
Interpretation of Oxide thickness for known nitride from previous step
Nitride Thickness
Nitride & Oxide thickness



1Dimensional plot of MF for Oxide Residues where Nitride thickness is known.

Fig 1